

ELECTROLYTE COMPOSITION AND NON-AQUEOUS ELECTROLYTE SECONDARY CELL

FIELD OF THE INVENTION

The present invention relates to an electrolyte composition useful for an anti-static agent, an electrochemical device, etc. and a non-aqueous electrolyte secondary cell comprising the electrolyte composition.

BACKGROUND OF THE INVENTION

Conventionally, a liquid electrolyte composition comprising a solvent and an electrolyte salt dissolved therein has been used for electrochemical devices such as a cell, a capacitor, a sensor, a display device, a recording device, etc. However, the electrochemical devices using such a liquid electrolyte composition are unreliable because they often cause leakage or depletion of the liquid electrolyte composition during long-term operation or storage.

Recently, researches have been actively in progress for solidifying the liquid electrolyte composition to prevent the leakage and depletion and to improve the reliability of the electrochemical device. For example, methods where the liquid electrolyte composition is infiltrated into a polymer matrix to prepare a so-called gel electrolyte composition has been disclosed in R. Koksang et al., Solid State Ionics, 69, 320 (1994), etc. Although this method can solidify the liquid electrolyte composition without reduction of the charge-transporting property of the electrolyte salt, volatilization of the solvent cannot be completely prevented. Further, a so-called, Polymer-in-salt-type solid electrolyte composition, which is prepared by radical-polymerizing a monomer such as a (meth)acrylate monomer in a room temperature molten salt having a low volatility, has been proposed. However, a secondary cell using the Polymer-in-salt-type solid electrolyte composition is insufficient in the cell characteristics, and further, preparation of this electrolyte composition requires a

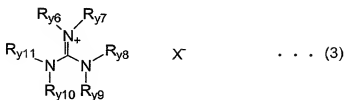
polymerization initiator, a radical-generating apparatus such as a light source, etc. to be complicated in operation.

OBJECT AND SUMMARY OF THE INVENTION

5 An object of the present invention is to provide an electrolyte composition excellent in a charge-transporting property (ionic conductivity) that can be prepared with ease, and a non-aqueous electrolyte secondary cell that comprises the electrolyte composition to exhibit excellent cell characteristics while preventing leakage or depletion of the electrolyte composition.

10 As a result of intense research in view of the above object, the inventor has found that an electrolyte composition excellent in charge-transporting property can be easily prepared by conducting a reaction between an electrophile having at least two polarized unsaturated bonds and a nucleophile having a plurality of nucleophilic groups in a molten salt, and that a non-
15 aqueous electrolyte secondary cell using the electrolyte composition exhibits excellent cell characteristics. The present invention has been accomplished by the findings.

20 Thus, an electrolyte composition of the present invention comprises: a molten salt represented by any of the following general formulae (1), (2) and (3); a polymer prepared by a reaction between an electrophile having at least two unsaturated bonds polarized by an electron-withdrawing group and a nucleophile having a plurality of nucleophilic groups; and a metal salt containing a Group IA metal ion or a Group IIA metal ion.



In the general formulae (1), (2) and (3), Q_{y1} represents an atomic group forming an aromatic cation having a 5- or 6-membered ring structure with the nitrogen atom, A_{y1} represents a nitrogen atom or a phosphorus atom, R_{y1} to R_{y11} independently represent a substituted or unsubstituted alkyl group or a substituted or unsubstituted alkenyl group, X⁻ represents an anion, two or more of R_{y2} to R_{y5} in the general formula (2) optionally bond together to form a non-aromatic ring containing A_{y1}, and two or more of R_{y6} to R_{y11} in the general formula (3) optionally bond together to form a ring.

A non-aqueous electrolyte secondary cell of the present invention comprises the above electrolyte composition of the present invention.

With respect to the electrolyte composition and the non-aqueous electrolyte secondary cell according to the present invention, the charge-transporting property and the cell characteristics are further improved by satisfying any of the following conditions (1) to (5).

(1) The molten salt represented by any of the general formulae (1), (2) and (3)

preferably has a melting point of 100 °C or less.

(2) Q_{y1} is preferably composed of atoms selected from the group consisting of carbon, hydrogen, nitrogen, oxygen and sulfur atoms.

(3) The aromatic cation formed by Q_{y1} is particularly preferably an imidazolium cation or a pyridinium cation.

(4) The electron-withdrawing group is preferably selected from the group consisting of a sulfonyl group, a cyano group and a carbonyl group.

(5) The nucleophilic groups are preferably selected from the group consisting of $-NH_2$, $-SH$, $-S^-$, $-SO_2H$ and $-SO_2^-$.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view showing an embodiment of the non-aqueous electrolyte secondary cell according to the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[1] Electrolyte Composition

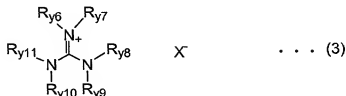
An electrolyte composition according to the present invention is usable for a solvent for chemical reactions, metal plating, etc., a CCD (charge coupling device) camera, various kinds of photoelectric conversion devices or cells, etc.

The electrolyte composition is particularly preferably used for a non-aqueous electrolyte secondary cell such as a lithium ion secondary cell, etc. The constituents of the electrolyte composition of the present invention will be described in detail below.

(A) Molten Salt

The electrolyte composition of the present invention comprises a molten salt represented by any of the following general formulae (1), (2) and (3). The molten salt is preferably such a salt that is in a liquid state at a room temperature (around 25 °C), a so-called "room temperature-molten salt". A melting point of

the molten salt is preferably 100 °C or less, more preferably 80 °C or less, particularly preferably 60 °C or less.



There are many cases where the molten salt represented by any of the general formulae (1), (2) and (3) can be used as the electrolyte with little or no solvent. Even if the molten salt is in a solid state at a room temperature, the molten salt may be liquefied by adding a little amount of solvent or additive thereto, to be used as the electrolyte. Alternatively, the molten salt may be incorporated in the secondary cell without any solvents or additives by: a method where the molten salt is heat-melted and penetrates into an electrode of the secondary cell; a method comprising the steps of dissolving the molten salt in a low boiling solvent such as methanol, acetonitrile and methylene chloride, making the resultant solution penetrate into an electrode, and evaporating the low boiling solvent by heating; etc.

In the general formula (1), Q_{y1} represents an atomic group forming an

aromatic cation having a 5- or 6-membered ring structure with the nitrogen atom, and R_{y1} represents a substituted or unsubstituted alkyl group, or a substituted or unsubstituted alkenyl group. Q_{y1} is preferably composed of atoms selected from the group consisting of carbon atoms, hydrogen atoms, nitrogen atoms, oxygen atoms and sulfur atoms. The 5-membered ring formed by Q_{y1} is preferably an oxazole ring, a thiazole ring, an imidazole ring, a pyrazole ring, an *iso*-oxazole ring, a thiadiazole ring, an oxadiazole ring or a triazole ring, more preferably a thiazole ring, a triazole ring, or an imidazole ring, particularly preferably an imidazole ring. The 6-membered ring formed by Q_{y1} is preferably a pyridine ring, a pyrimidine ring, a pyridazine ring, a pyrazine ring or a triazine ring, particularly preferably a pyridine ring.

In the general formula (2), A_{y1} represents a nitrogen atom or a phosphorus atom, and R_{y2} to R_{y5} independently represent a substituted or unsubstituted alkyl group, or a substituted or unsubstituted alkenyl group. Two or more of R_{y2} to R_{y5} in the general formula (2) may bond together to form a non-aromatic ring containing A_{y1} . The non-aromatic ring preferably has a 5- to 8-membered ring structure, more preferably has a 5- or 6-membered ring structure.

In the general formula (3), R_{y6} to R_{y11} independently represent a substituted or unsubstituted alkyl group, or a substituted or unsubstituted alkenyl group. Two or more of R_{y6} to R_{y11} in the general formula (3) may bond together to form a ring, and the ring preferably has a 5- to 8-membered ring structure, more preferably has a 5- or 6-membered ring structure.

With respect to the substituted or unsubstituted alkyl group represented by each of R_{y1} to R_{y11} , the alkyl group preferably has 1 to 24 carbon atom and may be straight, branched or cyclic, and examples thereof include a methyl group, an ethyl group, a propyl group, an isopropyl group, a butyl group, a pentyl group, a hexyl group, an octyl group, a 2-ethylhexyl group, a *t*-octyl group, a decyl group, a dodecyl group, a tetradecyl group, a 2-hexyldecyl group, an octadecyl group, a cyclohexyl group, a cyclopentyl group, etc. With respect to

the substituted or unsubstituted alkenyl group represented by each of R_{y1} to R_{y11} , the alkenyl group preferably has 2 to 24 carbon atoms and may be straight, branched or cyclic, and examples thereof include a vinyl group, an allyl group, etc. Each of R_{y1} to R_{y11} is preferably an alkyl group having 2 to 12 carbon atoms or an alkenyl group having 2 to 18 carbon atoms, more preferably an alkyl group having 2 to 6 carbon atoms.

Q_{y1} and R_{y1} to R_{y11} in the general formulae (1), (2) and (3) may have a substituent, respectively. Preferred examples of the substituent include: alkyl groups such as a methyl group, an ethyl group, a propyl group, an isopropyl group, a cyclopropyl group, a butyl group, an octyl group, a 2-carboxyethyl group and a benzyl group; alkenyl groups such as a vinyl group, an allyl group and a 1-propenyl group; aryl groups such as a phenyl group, a methoxyphenyl group and a tolyl group; substituted or unsubstituted silyl groups such as a trimethylsilyl group, a *t*-butyldimethylsilyl group, a phenyldimethylsilyl group and $-(Si(CH_3)_2O)_n-Si(CH_3)_3$; silyloxy groups such as a trimethylsilyloxy group, a *t*-butyldimethylsilyloxy group and a triethoxysilyloxy group; alkoxy groups such as a methoxy group, an ethoxy group, $-(OCH_2CH_2)_n-OCH_3$ and $-(OCH_2CH_2)_n-OCH_2CH_3$; aryloxy groups such as a phenoxy group and a 4-methoxyphenoxy group; alkoxycarbonyl groups such as a methoxycarbonyl group, an ethoxycarbonyl group and a phenoxycarbonyl group; carbonate groups such as an ethoxycarbonyloxy group and a phenoxycarbonyloxy group; acyl groups such as an acetyl group, a propionyl group and a benzoyl group; sulfonyl groups such as a methane sulfonyl group and a benzene sulfonyl group; acyloxy groups such as an acetoxy group and a benzoyloxy group; sulfonyloxy groups such as a methane sulfonyloxy group and a toluene sulfonyloxy group; phosphonyl groups such as a diethylphosphonyl group; amino groups such as an unsubstituted amino group, a dimethylamino group, a diethylamino group and an anilino group; amido groups such as an acetylamino group and a benzoylamino group; a guanidino group; carbamoyl groups such as an *N,N*-dimethylcarbamoyl group

and an *N*-phenylcarbamoyl group; a cyano group; alkylthio groups such as a methylthio group and an ethylthio group; heterocyclic groups such as a pyridyl group, an imidazolyl group and a furanyl group; halogen atoms such as a fluorine atom, a chlorine atom, a bromine atom and an iodine atom; etc.

5 Incidentally, the above "n" represents an integer of 1 to 20, respectively.

The molten salt represented by the general formula (1), (2) or (3) may form an oligomer or a polymer through any of Q_{y1} and R_{y1} to R_{y11} . The oligomer (or polymer) is preferably a dimer, a trimer or a tetramer, more preferably a dimer.

In the general formulae (1), (2) and (3), X^- represents an anion. Preferred examples of X^- include halide ions such as I^- , Cl^- and Br^- , SCN^- , BF_4^- , PF_6^- , ClO_4^- , SbF_6^- , $(CF_3SO_2)_2N^-$, $(CF_3CF_2SO_2)_2N^-$, Ph_4B^- , $(C_2H_4O_2)_2B^-$, $(CF_3SO_2)_3C^-$, CF_3COO^- , $CF_3SO_3^-$, $C_6F_5SO_3^-$, etc. X^- is particularly preferably SCN^- , BF_4^- , PF_6^- , ClO_4^- , SbF_6^- , $(CF_3SO_2)_2N^-$, $(CF_3CF_2SO_2)_2N^-$, $(CF_3SO_2)_3C^-$ or $CF_3SO_3^-$.

The molten salt represented by the general formula (1), (2) or (3) may be used in combination with another molten salt. The content of the molten salt is preferably 50 weight % or more, more preferably 70 weight % or more, based on the entire electrolyte composition. Examples of the molten salt used in the present invention will be illustrated below without intention of restricting the scope of the present invention defined by the claims attached hereto.

Y1



Y1-1: $X = \text{BF}_4^-$
 Y1-2: $X = \text{N}^-(\text{SO}_2\text{CF}_3)_2$
 Y1-3: $X = \text{PF}_6^-$

Y2



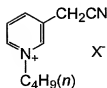
Y2-1: $X = \text{BF}_4^-$
 Y2-2: $X = \text{N}^-(\text{SO}_2\text{CF}_3)_2$
 Y2-3: $X = \text{CF}_3\text{COO}^-$
 Y2-4: $X = \text{SCN}^-$
 Y2-5: $X = \text{CF}_3\text{SO}_3^-$

Y3



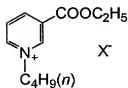
Y3-1: $X = \text{BF}_4^-$
 Y3-2: $X = \text{N}^-(\text{SO}_2\text{CF}_3)_2$

Y4



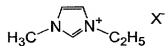
Y4-1: $X = \text{BF}_4^-$
 Y4-2: $X = \text{N}^-(\text{SO}_2\text{CF}_3)_2$

Y5

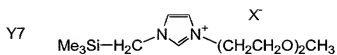


Y5-1: $X = \text{BF}_4^-$
 Y5-2: $X = \text{N}^-(\text{SO}_2\text{CF}_3)_2$

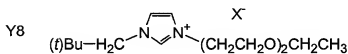
Y6



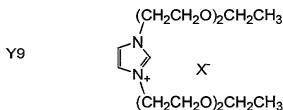
Y6-1: $X = \text{BF}_4^-$
 Y6-2: $X = \text{N}^-(\text{SO}_2\text{CF}_3)_2$
 Y6-3: $X = \text{CF}_3\text{COO}^-$
 Y6-4: $X = \text{SCN}^-$
 Y6-5: $X = \text{CF}_3\text{SO}_3^-$



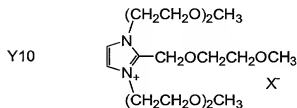
Y7-1: $X^- = \text{BF}_4^-$
 Y7-2: $X^- = \text{N}^-(\text{SO}_2\text{CF}_3)_2$
 Y7-3: $X^- = \text{CF}_3\text{COO}^-$
 Y7-4: $X^- = \text{SCN}^-$



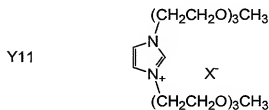
Y8-1: $X^- = \text{BF}_4^-$
 Y8-2: $X^- = \text{N}^-(\text{SO}_2\text{CF}_3)_2$
 Y8-3: $X^- = \text{PF}_6^-$
 Y8-4: $X^- = \text{CF}_3\text{COO}^-$
 Y8-5: $X^- = \text{SCN}^-$
 Y8-6: $X^- = \text{CF}_3\text{SO}_3^-$



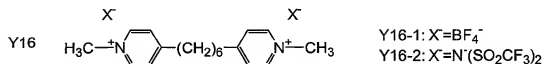
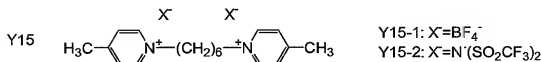
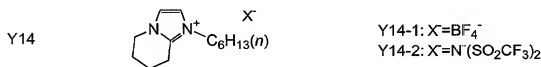
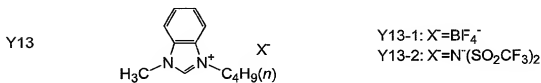
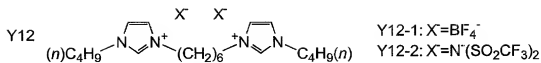
Y9-1: $X^- = \text{BF}_4^-$
 Y9-2: $X^- = \text{N}^-(\text{SO}_2\text{CF}_3)_2$
 Y9-3: $X^- = \text{CF}_3\text{COO}^-$
 Y9-4: $X^- = \text{SCN}^-$
 Y9-5: $X^- = \text{CF}_3\text{SO}_3^-$

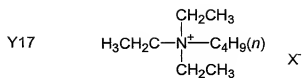


Y10-1: $X^- = \text{BF}_4^-$
 Y10-2: $X^- = \text{N}^-(\text{SO}_2\text{CF}_3)_2$

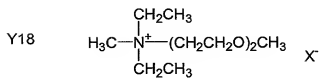


Y11-1: $X^- = \text{BF}_4^-$
 Y11-2: $X^- = \text{N}^-(\text{SO}_2\text{CF}_3)_2$

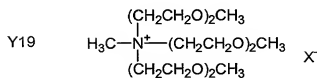




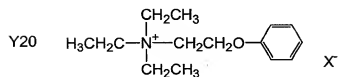
Y17-1: $\text{X}^-=\text{BF}_4^-$
 Y17-2: $\text{X}^-=\text{N}^+(\text{SO}_2\text{CF}_3)_2$
 Y17-3: $\text{X}^-=\text{PF}_6^-$



Y18-1: $\text{X}^-=\text{BF}_4^-$
 Y18-2: $\text{X}^-=\text{N}^+(\text{SO}_2\text{CF}_3)_2$



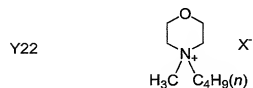
Y19-1: $\text{X}^-=\text{BF}_4^-$
 Y19-2: $\text{X}^-=\text{N}^+(\text{SO}_2\text{CF}_3)_2$
 Y19-3: $\text{X}^-=\text{CF}_3\text{COO}^-$
 Y19-4: $\text{X}^-=\text{SCN}^-$
 Y19-5: $\text{X}^-=\text{CF}_3\text{SO}_3^-$



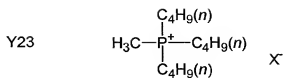
Y20-1: $\text{X}^-=\text{BF}_4^-$
 Y20-2: $\text{X}^-=\text{N}^+(\text{SO}_2\text{CF}_3)_2$



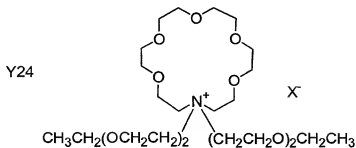
Y21-1: $\text{X}^-=\text{BF}_4^-$
 Y21-2: $\text{X}^-=\text{N}^+(\text{SO}_2\text{CF}_3)_2$



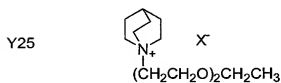
Y22-1: $\text{X}^-=\text{BF}_4^-$
 Y22-2: $\text{X}^-=\text{N}^+(\text{SO}_2\text{CF}_3)_2$



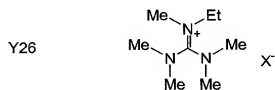
Y23-1: $\text{X}=\text{BF}_4^-$
Y23-2: $\text{X}=\text{N}^-(\text{SO}_2\text{CF}_3)_2$



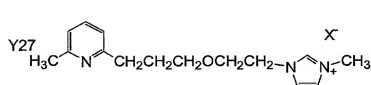
Y24-1: $\text{X}=\text{BF}_4^-$
Y24-2: $\text{X}=\text{N}^-(\text{SO}_2\text{CF}_3)_2$



Y25-1: $\text{X}=\text{BF}_4^-$
Y25-2: $\text{X}=\text{N}^-(\text{SO}_2\text{CF}_3)_2$

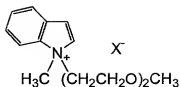


Y26-1: $\text{X}=\text{BF}_4^-$
Y26-2: $\text{X}=\text{N}^-(\text{SO}_2\text{CF}_3)_2$
Y26-3: $\text{X}=\text{PF}_6^-$

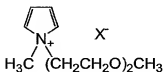


Y27-1: $\text{X}=\text{BF}_4^-$
Y27-2: $\text{X}=\text{N}^-(\text{SO}_2\text{CF}_3)_2$
Y27-3: $\text{X}=\text{CF}_3\text{COO}^-$
Y27-4: $\text{X}=\text{SCN}^-$
Y27-5: $\text{X}=\text{CF}_3\text{SO}_3^-$

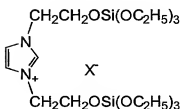
Y28

Y28-1: $\text{X}^- = \text{BF}_4^-$ Y28-2: $\text{X}^- = \text{N}^-(\text{SO}_2\text{CF}_3)_2$

Y29

Y29-1: $\text{X}^- = \text{BF}_4^-$ Y29-2: $\text{X}^- = \text{N}^-(\text{SO}_2\text{CF}_3)_2$

Y30

Y30-1: $\text{X}^- = \text{BF}_4^-$ Y30-2: $\text{X}^- = \text{N}^-(\text{SO}_2\text{CF}_3)_2$ Y30-3: $\text{X}^- = \text{PF}_6^-$ Y30-4: $\text{X}^- = \text{CF}_3\text{SO}_3^-$ Y30-5: $\text{X}^- = \text{C}(\text{O}_4)^-$

(B) Polymer

The electrolyte composition of this invention comprises a polymer, which is prepared by a reaction between an electrophile having at least two polarized unsaturated bonds and a nucleophile having a plurality of nucleophilic groups. Thus, the polymer used in the present invention is not a conventional polymer prepared by a radical polymerization, but a cross-linked polymer easily prepared by a Michael-type reaction where the nucleophile is added to the polarized unsaturated bond. (i) Electrophile, (ii) Nucleophile and (iii) Preparation of Polymer will be explained in detail below.

(i) Electrophile

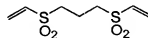
The electrophile used in the present invention has at least two unsaturated bonds polarized by an electron-withdrawing group. The number of the unsaturated bonds in a molecule of the electrophile is preferably 2 to 10, more preferably 2 to 6. The unsaturated bonds may be a double bond or a triple bond, respectively.

The electron-withdrawing group may be a sulfonyl group, a cyano group, a carbonyl group, an imino group, a thiocarbonyl group, a sulfinyl group, etc., and is preferably a sulfonyl group, a cyano group or a carbonyl group, more preferably a sulfonyl group or a cyano group. The electrophile may have a plurality of the electron-withdrawing groups, and in this case, the electron-withdrawing groups may be the same or different each other. Examples of the electrophile used in the present invention will be illustrated below without intention of restricting the scope of the present invention defined by the claims attached hereto.

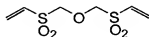
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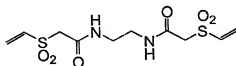
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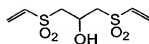
1-3



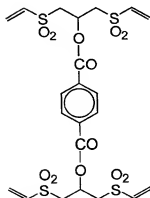
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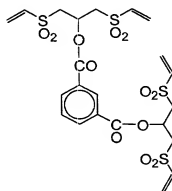
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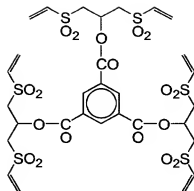
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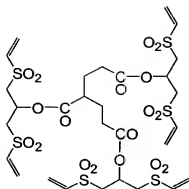
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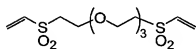
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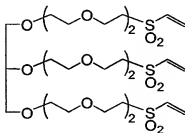
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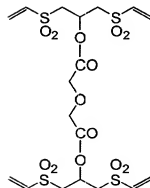
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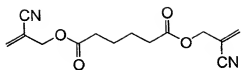
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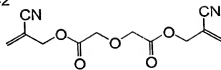
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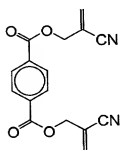
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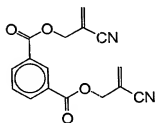
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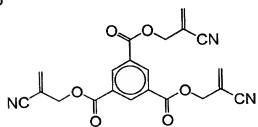
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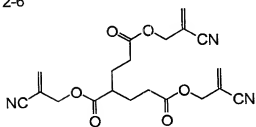
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2-5



2-6



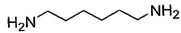


(ii) Nucleophile

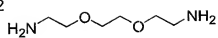
The nucleophile used in this invention has a plurality of nucleophilic groups. The number of the nucleophilic groups in a molecule of the nucleophile is preferably 2 to 10, more preferably 2 to 6. The sum total of the number of the nucleophilic groups in the nucleophile and the number of the unsaturated bonds in the electrophile is preferably 5 to 12, more preferably 5 to 10.

The nucleophilic group is not particularly limited if only it has a lone pair or a negative charge and can attack the electrophile to bond thereto providing two bonding electrons. Examples of the nucleophilic group include -NH₂, -SH, -S⁻, -SO₂H, -SO₂⁻, -OH, -COOH, etc. Among them, preferred are -NH₂, -SH, -S⁻, -SO₂H and -SO₂⁻, particularly preferred is -NH₂. Incidentally, -S⁻, -SO₂⁻, etc. may have an appropriate counter ion. Examples of the nucleophile used in the present invention will be illustrated below without intention of restricting the scope of the present invention defined by the claims attached hereto.

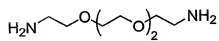
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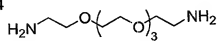
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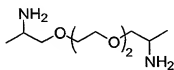
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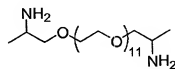
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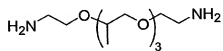
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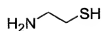
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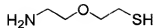
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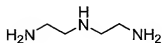
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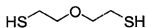
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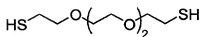
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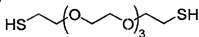
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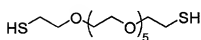
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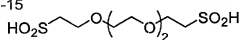
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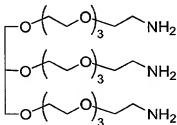
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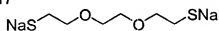
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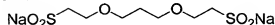
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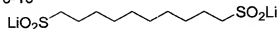
3-17



3-18



3-19



(iii) Preparation of Polymer

The polymer may be prepared by adding the electrophile and the nucleophile to the molten salt of the general formula (1), (2) or (3), thereby carrying out the reaction between the electrophile and the nucleophile under a mild condition. To the reaction mixture may be added a solvent, an additive

such as a catalyst, etc. A reaction temperature and a reaction period are not particularly limited. The reaction temperature is preferably 0 to 150 °C, more preferably 10 to 100 °C. The reaction period is preferably 5 minutes to 2 days, more preferably 10 minutes to 1 day.

5 Amounts of the electrophile and the nucleophile are preferably controlled such that a ratio nu/m , which means a ratio of the total number nu of the nucleophilic groups in all nucleophile molecules to the total number m of the unsaturated bonds in all electrophile molecules, is 0.2 to 5 in the reaction mixture. The ratio nu/m is more preferably 0.3 to 2, particularly preferably 0.3 to 1.

A weight ratio of the total of the electrophile and the nucleophile is preferably 0.1 to 80 weight %, more preferably 0.5 to 50 weight %, particularly preferably 1 to 30 weight % based on 100 weight % of the molten salt represented by the general formula (1), (2) or (3).

(C) Metal Salt

The electrolyte composition of the present invention comprises a metal salt containing a Group IA metal ion or a Group IIA metal ion. The metal salt is preferably a lithium salt, a sodium salt or a potassium salt, particularly preferably a lithium salt. Examples of the metal salt include $LiCF_3SO_3$, $LiPF_6$, $LiClO_4$, LiI , $LiBF_4$, $LiCF_3CO_2$, $LiSCN$, $LiN(SO_2CF_3)_2$, NaI , $NaCF_3SO_3$, $NaClO_4$, $NaBF_4$, $NaAsF_6$, KCF_3SO_3 , $KSCN$, KPF_6 , $KClO_4$, $KAsF_6$, etc. The metal salt may be used singly or in combination with the other metal salt.

20 A mole ratio of the metal salt is preferably 0.1 to 8 mole equivalent, more preferably 0.3 to 3 mole equivalent, per 1 mole equivalent of the molten salt represented by the general formula (1), (2) or (3).

(D) Solvent

The electrolyte composition may comprise a solvent. A weight of the

other.

[2] Non-Aqueous Electrolyte Secondary Cell

A non-aqueous electrolyte secondary cell of the present invention
5 comprises the electrolyte composition, whereby the non-aqueous electrolyte
secondary cell is excellent in cell characteristics and hardly cause leakage or
depletion of the electrolyte composition during long-term operation or storage.
An internal structure and a production method of the non-aqueous electrolyte
secondary cell according to this invention are not particularly limited.

In the non-aqueous electrolyte secondary cell, the electrolyte
composition may be used in combination with a positive electrode, a negative
electrode, a jacket material, a separator, a control circuit, etc. For example, the
non-aqueous electrolyte secondary cell according to an embodiment of the
present invention may be a lithium secondary cell comprising: the electrolyte
composition of the present invention; a positive electrode composed of a
cathode active material that occludes or releases lithium as a main component,
and a conductant agent, a collector, etc.; a negative electrode composed of an
anode active material that occludes or releases lithium, and a conductant agent, a
collector, etc.; and a jacket material.

Purpose, application and use of the non-aqueous electrolyte secondary
cell of the present invention are not particularly limited. For example, the non-
aqueous electrolyte secondary cell may be installed and used in an electronic
equipment such as a notebook-sized personal computer, a pen input-type
personal computer, a mobile personal computer, an electronic book player, a
portable telephone, a cordless handset, a pager, a handy terminal, a portable
facsimile, a portable copying machine, a portable printer, a headphone stereo
receiver, a video movie, a liquid crystal television, a handy cleaner, a portable
CD player, a mini-disc player, an electric shaver, an electronic transceiver, an
electronic notebook, an electronic calculator, a memory card, a portable tape

recorder, a radio, a backup power source, etc. The non-aqueous electrolyte secondary cell may be used for a motor, a lighting fixture, a toy, a game machine, a load conditioner, a clock, a strobe, a camera, a medical instrument such as a pacemaker, a hearing aid and a shoulder massager, etc. Further, the non-aqueous electrolyte secondary cell may be used in combination with a solar cell.

EXAMPLES

The present invention will be explained in more detail with reference to examples below without intention of restricting the scope of the present invention.

1. Preparation of Electrolyte Composition Film

(a) Films *F-1* to *F-15*

0.9 g of LiBF_4 was added to 2.2 g of a molten salt *Y1-2* and dissolved therein. To this mixture was added 0.15 g of an electrophile *1-6* at 25 °C, and 0.05 g of a nucleophile *3-3* was then added thereto and stirred. Polymerization reaction proceeded in the resulting reaction mixture, so that this was rapidly cast on a teflon plate and the polymerization reaction was allowed to proceed on the teflon plate for 2 hours, to prepare a film *F-1* of an electrolyte composition according to the present invention. Further, films *F-2* to *F-15* each composed of an electrolyte composition according to the present invention were prepared in the same manner as the film *F-1* except for using a molten salt, materials for a polymer (an electrophile and a nucleophile) and a metal salt shown in Table 1, respectively. Incidentally, each of the films *F-1* to *F-15* had a thickness of 50 μm .

(b) Films *F-16* and *F-17*

To 3.9 g of a molten salt *Y6-2* was added 0.2 g of 2-

hydroxyethylmethacrylate (HEMA) and ethyleneglycol dimethacrylate (EGDMA) as monomers, mole ratio of EGDMA to HEMA being 2 mol %. To the resultant mixture was added 2.9 g of $\text{LiN}(\text{SO}_2\text{CF}_3)_2$, and then, a polymerization initiator of benzoyl peroxide was added thereto and mixed.

- 5 Mole ratio of benzoyl peroxide was 2 mol % based on 100 mol % of the monomers. Thus-obtained reaction mixture was rapidly cast on a teflon plate and polymerization was allowed to proceed thereon at 80 °C for 12 hours, to prepare a film *F-16* of a comparative electrolyte composition. Further, a film *F-17* of a comparative electrolyte composition was prepared in the same manner as the film *F-1* except for using 3.9 g of propylene carbonate (PC) as a solvent instead of the molten salt *Y1-2*, changing amount of the materials for a polymer and using a metal salt shown in Table 1.

The molten salt, the materials for the polymer and the metal salt used for each of thus-obtained films and amounts thereof were shown in Table 1. Further, an ionic conductivity of each film was also shown in Table 1. The ionic conductivity was obtained by a Cole-Cole plot of impedance measured at 25 °C, 100000 to 0.1 Hz.

Table 1

Film	Molten Salt (Amount)	Materials for Polymer (Amount)	Metal Salt (Amount)	Ionic Conductivity S/cm
F-1	Y1-1 (2.2 g)	1-6 (0.15 g), 3-3 (0.05 g)	LiBF ₄ (0.9 g)	6.0×10^{-4}
F-2	Y6-1 (2.0 g)	1-6 (0.14 g), 3-3 (0.05 g)	LiBF ₄ (0.9 g)	6.1×10^{-4}
F-3	Y6-2 (3.9 g)	1-6 (0.2 g), 3-3 (0.07 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	6.3×10^{-4}
F-4	Y6-2 (3.9 g)	1-6 (0.16 g), 3-3 (0.05 g)	LiPF ₆ (1.5 g)	6.0×10^{-4}
F-5	Y6-2 (3.9 g)	1-9 (0.2 g), 3-3 (0.07 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	6.2×10^{-4}
F-6	Y6-2 (3.9 g)	1-12 (0.2 g), 3-4 (0.07 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	6.1×10^{-4}
F-7	Y6-2 (3.9 g)	2-5 (0.15 g), 3-3 (0.08 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	6.0×10^{-4}
F-8	Y6-2 (3.9 g)	2-9 (0.15 g), 3-3 (0.08 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	6.0×10^{-4}
F-9	Y6-2 (3.9 g)	2-11 (0.15 g), 3-4 (0.08 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	6.1×10^{-4}
F-10	Y6-2 (3.9 g)	2-11 (0.15 g), 3-12 (0.08 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	6.2×10^{-4}
F-11	Y6-2 (3.9 g)	2-11 (0.15 g), 3-19 (0.08 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	6.2×10^{-4}
F-12	Y6-5 (2.6 g)	1-6 (0.13 g), 3-3 (0.04 g)	Li(CF ₃ SO ₃) (1.6 g)	6.2×10^{-4}
F-13	Y9-2 (5.8 g)	1-6 (0.26 g), 3-3 (0.08 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	6.1×10^{-4}
F-14	Y18-2 (4.7 g)	1-6 (0.23 g), 3-3 (0.08 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	6.2×10^{-4}
F-15	Y26-2 (4.4 g)	1-6 (0.14 g), 3-3 (0.05 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	6.2×10^{-4}
F-16	Y6-2 (3.9 g)	HEMA (0.2 g), EGDMA	LiN(SO ₂ CF ₃) ₂ (2.9 g)	5.4×10^{-4}
F-17	-	1-6 (0.2 g), 3-3 (0.07 g)	LiN(SO ₂ CF ₃) ₂ (2.9 g)	1.0×10^{-3}

As shown in Table 1, the electrolyte compositions according to the present invention prepared under a mild condition exhibited a high ionic conductivity.

2. Production of Non-Aqueous Electrolyte Secondary Cell

(a) Preparation of Positive Electrode Sheet

To 100 parts by weight of acrylonitrile were added 43 parts by weight of LiCoO₂ and 2 parts by weight of a squamous graphite as cathode active materials, and further added 2 parts by weight of acetylene black. Then, 3 parts by weight of polyacrylonitrile was added as a binder thereto and mixed to prepare a slurry. Thus-obtained slurry was applied to an aluminum foil having a thickness of 20 μ m by means of an extrusion-type applying apparatus and dried. After drying, the resultant was press-formed into a sheet having a thickness of 95 μ m, a width of 54 mm and a length of 49 mm by a calendar press and an aluminum lead plate was weld to ends thereof, to prepare a positive electrode sheet CA-1.

5 A positive electrode sheet *CA-2* having a thickness of 114 μm , a width of 54 mm and a length of 49 mm was prepared in the same manner as the positive electrode sheet *CA-1* except for using LiMn_2O_4 instead of LiCoO_2 . Further, a positive electrode sheet *CA-3* having a thickness of 75 μm , a width of 54 mm and a length of 49 mm was prepared in the same manner as the positive electrode sheet *CA-1* except for using LiNiO_2 instead of LiCoO_2 .

(b) Preparation of Negative Electrode Sheet

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20 To 100 parts by weight of *N*-methylpyrrolidone were added 43 parts by weight of SnSiO_3 as an anode active material, 2 parts by weight of acetylene black and 2 parts by weight of graphite as conductant agents, and further, 3 parts by weight of polyacrylonitrile was added thereto as a binder and mixed to prepare a slurry for a negative electrode. Then, 100 parts by weight of *N*-methylpyrrolidone, 45 parts by weight of α -alumina, 7 parts by weight of graphite and 3 parts by weight of polyacrylonitrile were mixed with each other to prepare a slurry for an auxiliary layer. Thus-obtained slurry for a negative electrode was applied to a copper foil having a thickness of 10 μm , and the slurry for an auxiliary layer was further applied thereonto by means of an extrusion-type applying apparatus. After the applied slurries were dried, the resultant was press-formed into a sheet having a thickness of 46 μm , a width of 55 mm and a length of 50 mm by a calendar press and a nickel lead plate was weld to ends thereof. The resulting sheet was subjected to a heat treatment at 230 $^{\circ}\text{C}$ for 1 hour under a dried air having a dew-point of -40°C or less by means of a far-infrared ray heater, and lithium foils of 4 mm \times 55 mm in size having a thickness of 35 μm and a purity of 99.8 % were stuck on the entire surface of the sheet at a regular interval of 10 mm in a direction perpendicular to the longitudinal direction of the sheet, to prepare a negative electrode sheet *AN-1*.

A negative electrode sheet *AN-2* was prepared in the same manner as the negative electrode sheet *AN-1* except for using $\text{Sn}_{0.8}\text{Al}_{0.2}\text{B}_{0.3}\text{P}_{0.2}\text{Si}_{0.5}\text{O}_{3.6}$ instead of SnSiO_3 . Further, a negative electrode sheet *AN-3* was prepared in the same manner as the negative electrode sheet *AN-1* except for using

5 $\text{SnAl}_{0.4}\text{B}_{0.5}\text{Cs}_{0.1}\text{P}_{0.5}\text{O}_{3.65}$ instead of SnSiO_3 .

To 100 parts by weight of *N*-methylpyrrolidone were added 43 parts by weight of a mesophase pitch carbon material manufactured by Petoca Materials Ltd. as an anode active material, 2 parts by weight of acetylene black and 2 parts by weight of graphite as conductant agents. And further, 3 parts by weight of polyacrylonitrile was added thereto as a binder and mixed to prepare a slurry for a negative electrode. Thus-obtained slurry was applied to a copper foil having a thickness of 10 μm by means of an extrusion-type applying apparatus and dried. After drying, the resultant was press-formed into a sheet having a thickness of 46 μm , a width of 55 mm and a length of 50 mm by a calendar press and a nickel lead plate was weld to ends thereof. The resulting sheet was subjected to a heat treatment at 230 °C for 1 hour under a dried air having a dew-point of -40 °C or less by means of a far-infrared ray heater, to prepare a negative electrode sheet *AN-4*.

20 (c) Production of Sheet-Shaped Secondary Cell

The positive electrode sheet, the electrolyte composition film and the negative electrode sheet prepared as above were used to produce a sheet-shaped secondary cell shown in Fig. 1. First, the positive electrode sheet 1 (*CA-1*) having a width of 54 mm and a length of 49 mm combined with a positive electrode terminal 11, and the negative electrode sheet 3 (*AN-1*) having a width of 55 mm and a length of 50 mm combined with a negative electrode terminal 31 were subjected to dehydration and drying at 230 °C for 30 minutes under a dried air having a dew-point of -40 °C or less, respectively. Next, the positive electrode sheet 1, the electrolyte composition film 2 (*F-1*) cut into 60 mm × 60

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mm in size, and the negative electrode sheet 3 were stacked in this order under a dry condition as shown in Fig. 1. Then, a jacket material of a laminate film made of polyethylene (50 μm) and polyethylene terephthalate (50 μm) was heat-welded to the resulting stack under a vacuum condition to seal the stack, whereby a sheet-shaped secondary cell of Example 1 was produced.

Further, sheet-shaped secondary cells of Examples 2 to 11 and Comparative Examples 1 to 7 were produced in the same manner as Example 1 except for using the positive electrode sheet, the electrolyte composition film and the negative electrode sheet shown in Table 2, respectively.

Table 2

Secondary Cell	Positive Electrode Sheet	Negative Electrode Sheet	Electrolyte Composition Film
Ex. 1	CA-1	AN-1	F-1
Ex. 2	CA-1	AN-1	F-3
Ex. 3	CA-1	AN-1	F-7
Ex. 4	CA-1	AN-1	F-8
Ex. 5	CA-1	AN-1	F-10
Ex. 6	CA-1	AN-1	F-11
Ex. 7	CA-1	AN-2	F-3
Ex. 8	CA-1	AN-3	F-3
Ex. 9	CA-1	AN-4	F-3
Ex. 10	CA-2	AN-1	F-3
Ex. 11	CA-3	AN-1	F-3
Comp. Ex. 1	CA-1	AN-1	F-16
Comp. Ex. 2	CA-1	AN-2	F-16
Comp. Ex. 3	CA-1	AN-3	F-16
Comp. Ex. 4	CA-1	AN-4	F-16
Comp. Ex. 5	CA-2	AN-1	F-16
Comp. Ex. 6	CA-3	AN-1	F-16
Comp. Ex. 7	CA-1	AN-1	F-17

3. Evaluation

(a) Evaluation of Cell Characteristics

10 sheet-shaped secondary cells of Example 1 were produced as above, each of the secondary cells was charged and discharged repeatedly 10 times under a condition of 0.2 C, a charge final voltage of 4.2 V and a discharge final voltage of 2.6 V. Thus, each of the 10 sheet-shaped secondary cells was

measured with respect to a discharge capacitance at 10th cycle of the charge and discharge, whereby an average of the discharge capacitances was obtained as "capacitance" of the sheet-shaped secondary cell of Example 1. Capacitances of the sheet-shaped secondary cells of Examples 2 to 11 and Comparative Examples 1 to 7 were obtained in the same manner as the secondary cell of Example 1, respectively.

Then, the capacitances of the secondary cells of Examples 2 to 6 and Comparative Examples 1 and 7 were each divided by the capacitance of the secondary cell of Example 1 that uses the positive electrode sheet and the negative electrode sheet same as those used in Examples 2 to 6 and Comparative Examples 1 and 7, to provide "relative capacitance" of each secondary cell of Examples 2 to 6 and Comparative Examples 1 and 7. Equally, the capacitance of the secondary cell of Comparative Example 2 was divided by the capacitance of the secondary cell of Example 7, the capacitance of the secondary cell of Comparative Example 3 was divided by the capacitance of the secondary cell of Example 8, the capacitance of the secondary cell of Comparative Example 4 was divided by the capacitance of the secondary cell of Example 9, the capacitance of the secondary cell of Comparative Example 5 was divided by the capacitance of the secondary cell of Example 10, and the capacitance of the secondary cell of Comparative Example 6 was divided by the capacitance of the secondary cell of Example 11, to provide relative capacitances of the secondary cells of Comparative Examples 2 to 6, respectively.

Further, the secondary cells of Examples 1 to 11 and Comparative Examples 1 to 7 were charged and discharged repeatedly 300 times under a condition of 0.5 C, a charge final voltage of 4.2 V and a discharge final voltage of 2.6 V, respectively. Thus, each secondary cell was measured with respect to "cycle capacitance" that means a ratio of discharge capacitance at 300th cycle of the charge and discharge based in discharge capacitance at 10th cycle of the charge and discharge. The relative capacitance and the cycle capacitance of

each sheet-shaped secondary cell were shown in Table 3.

(b) Evaluation of Leakage

The jacket material was peeled off from one surface of each sheet-shaped secondary cell of Examples 1 to 11 and Comparative Examples 1 to 7, and a pressure of 200 g/cm² was applied thereto, whereby leakage of a liquid in each secondary cell was observed by visual observation. The results were shown in Table 3, where "A" means that the leakage was not observed, "B" means that the leakage was hardly observed, and "C" means that the leakage was observed.

Table 3

Secondary Cell	Relative Capacitance	Cycle Capacitance	Leakage
Ex. 1	1.00	0.85	A
Ex. 2	0.99	0.85	A
Ex. 3	0.98	0.84	A
Ex. 4	0.99	0.85	A
Ex. 5	0.97	0.85	A
Ex. 6	0.99	0.85	A
Ex. 7	1.01	0.84	A
Ex. 8	1.00	0.85	A
Ex. 9	1.00	0.84	A
Ex. 10	1.00	0.84	A
Ex. 11	1.00	0.84	A
Comp. Ex. 1	0.88	0.79	B
Comp. Ex. 2	0.87	0.78	B
Comp. Ex. 3	0.85	0.76	B
Comp. Ex. 4	0.77	0.78	B
Comp. Ex. 5	0.85	0.73	B
Comp. Ex. 6	0.85	0.79	B
Comp. Ex. 7	1.20	0.65	C

As shown in Table 3, the sheet-shaped secondary cells of Examples 1 to 11 according to the present invention were excellent in the capacitance and stability in repeated operation, and prevented the leakage of the electrolyte composition.

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As described in detail above, the electrolyte composition of the present invention is excellent in the charge-transporting property (ionic conductivity) and can be prepared with ease. The non-aqueous electrolyte secondary cell of the present invention comprising the electrolyte composition exhibits excellent cell characteristics while preventing leakage or depletion of the electrolyte composition.

1004137-12404